# Pyro-electro-catalytic disinfection using the pyroelectric effect of low Curie temperature, lead-free ferroelectric ceramics

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## Introduction

In recent years there has been an increasing interest in pyroelectric materials for energy harvesting applications, as they have the potential to convert temperature fluctuations into electrical energy. This work investigates using low Curie temperature ($T_c$), lead-free, ferroelectric ceramics for pyroelectric-electrochemical catalytic reactions, such as water splitting [1], dye degradation [2,3,4] and disinfection of water [5,6].

This work investigates barium strontium titanate (BST), with composition $Ba_{0.7}Sr_{0.3}TiO_3$, which has desirable pyroelectric properties for decontamination & disinfection of water:

- High pyroelectric coefficient, *p*
- High *p* to relative permittivity, $\varepsilon^{T}_{33}$, ratio
- Low $T_c$ – BST ≈ 35°C
- Environmental and sustainability advantage
  – lead free, comprising earth abundant elements

## Materials and Methods

BST powders were synthesised and used to produce a variety of materials structures, including finely ground powders, porous structures and dense materials. Freeze casting was used to produce porous materials with aligned pore structures which are beneficial for providing high polarisation and pore channels for high surface area contact with the solution. The powder, dense tablets and porous materials were characterised using:

- X-ray diffraction (XRD)
- Scanning electron microscopy (SEM)
- Phase angle, relative permittivity and conductivity vs. frequency measurements
- Polarisation – electric field (P-E) ferroelectric hysteresis loops

In this work, the powders and porous pyroelectric materials were placed in direct contact with the aqueous solutions containing bacteria to examine the potential of using temperature fluctuations and harnessing the pyroelectric effect for disinfection of water.

## Results

The water decontamination experiments were carried out using Escherichia coli (E. coli) strains BW25113 and NCTC 10418 in the presence of BST powders. Vials containing the bacteria and BST particles, alongside control vials containing the bacteria only solution, were thermally cycled six times from 25°C-45°C. The effectiveness of the pyroelectric BST powders for disinfection of the solutions was measured by counting and comparing the colony forming units (CFU) grown from the samples prior to & after the temperature cycling.

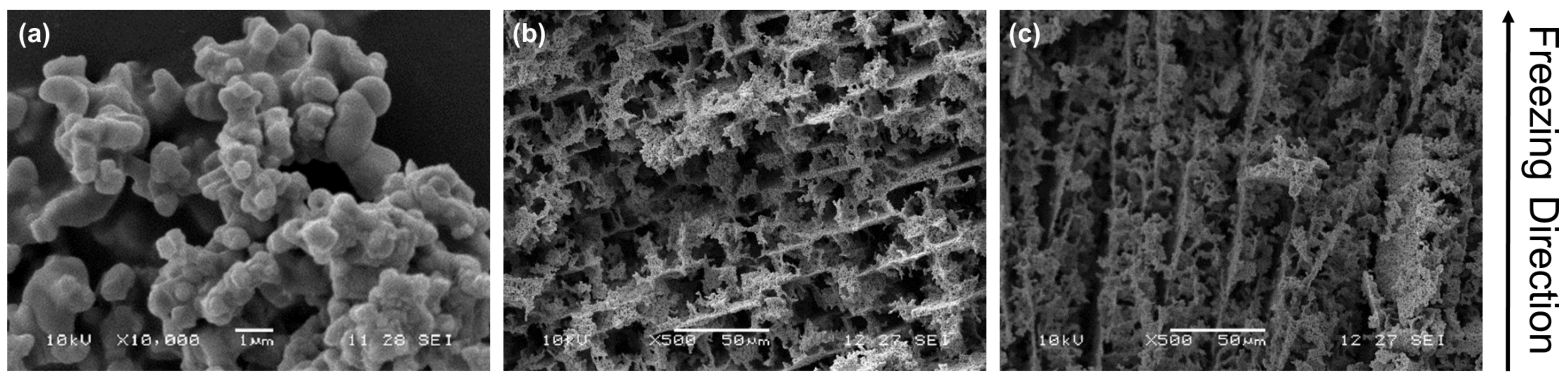


*Figure 1: SEM micrographs of (a) the milled BST powders at x10K magnification and of the freeze-cast 50wt% solid loading BST ceramics, where the pores are shown (b) perpendicular and (c) aligned parallel to the direction of freezing.*

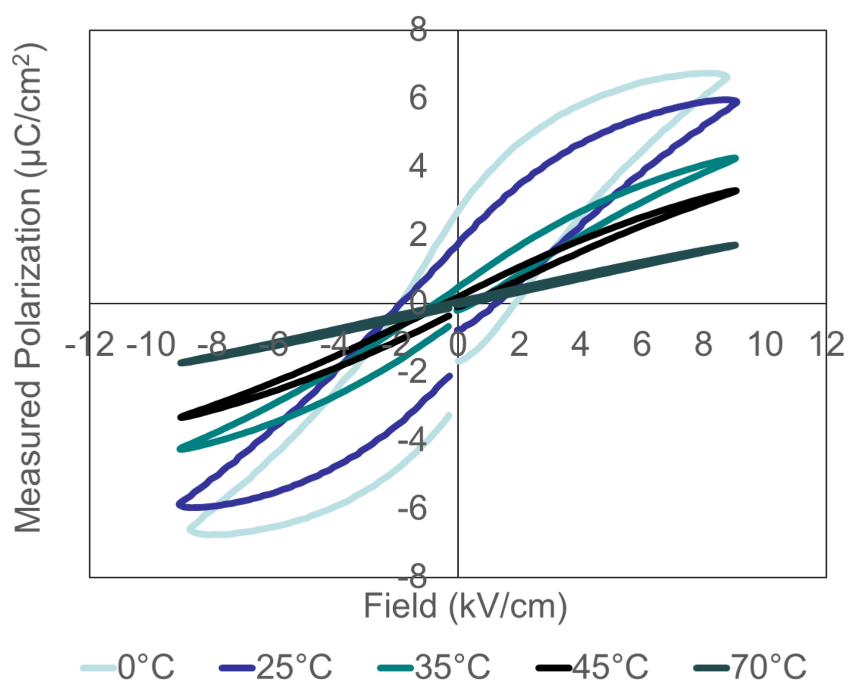


*Figure 2: P-E hysteresis loops for BST dense pressed tablet at a range of temperatures from 0°C to 70°C.*

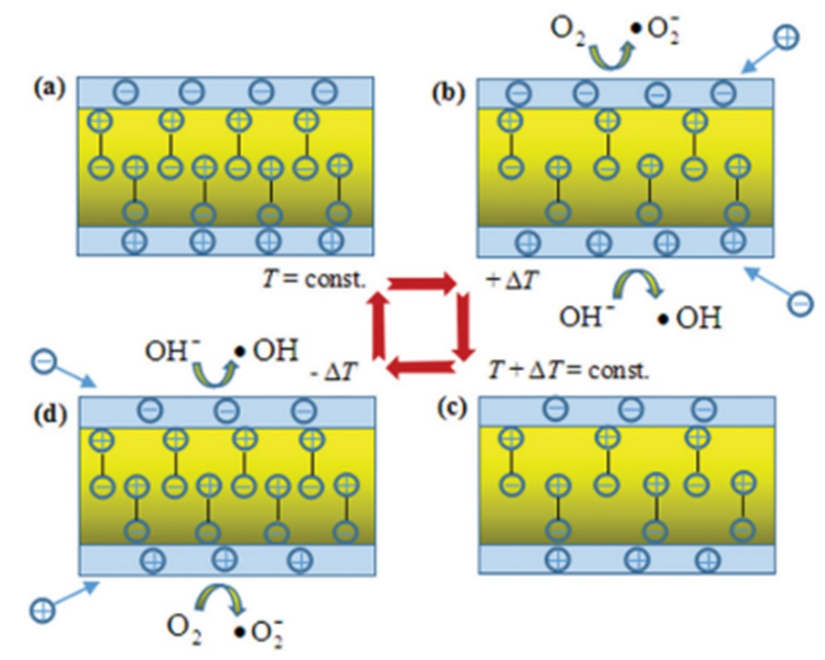


*Figure 3: Schematic representation of the production of reactive oxygen species (ROS) by the pyroelectric effect, reproduced from reference 3.*

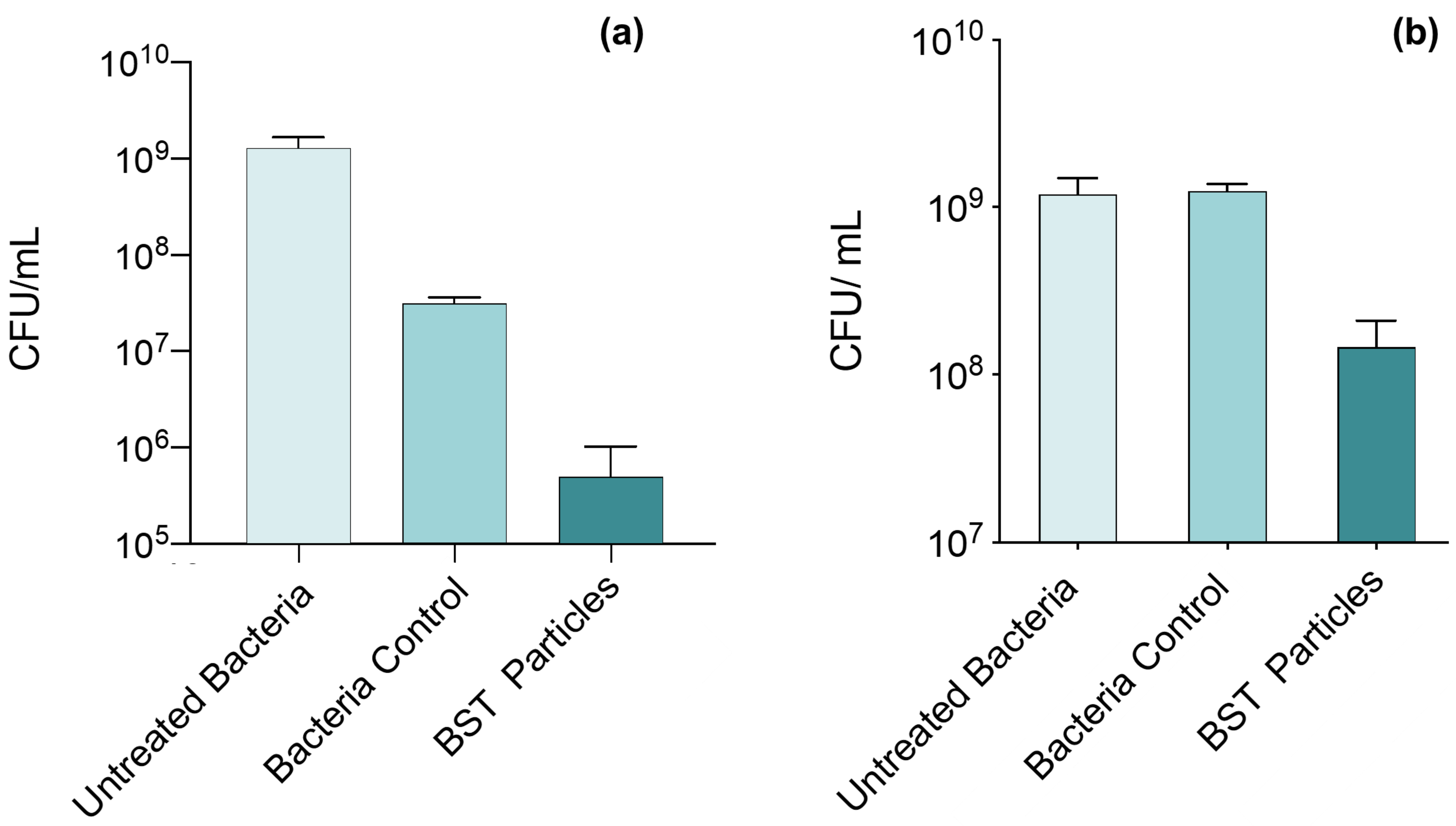


*Figure 5: Viable cell counts of Escherichia coli (a) BW25113 and (b) NCTC 10418 in the presence of pyroelectric BST particles after 6 temperature cycles (25°C-45°C) compared to the untreated bacteria culture and bacteria only solution after 6 temperature cycles.*

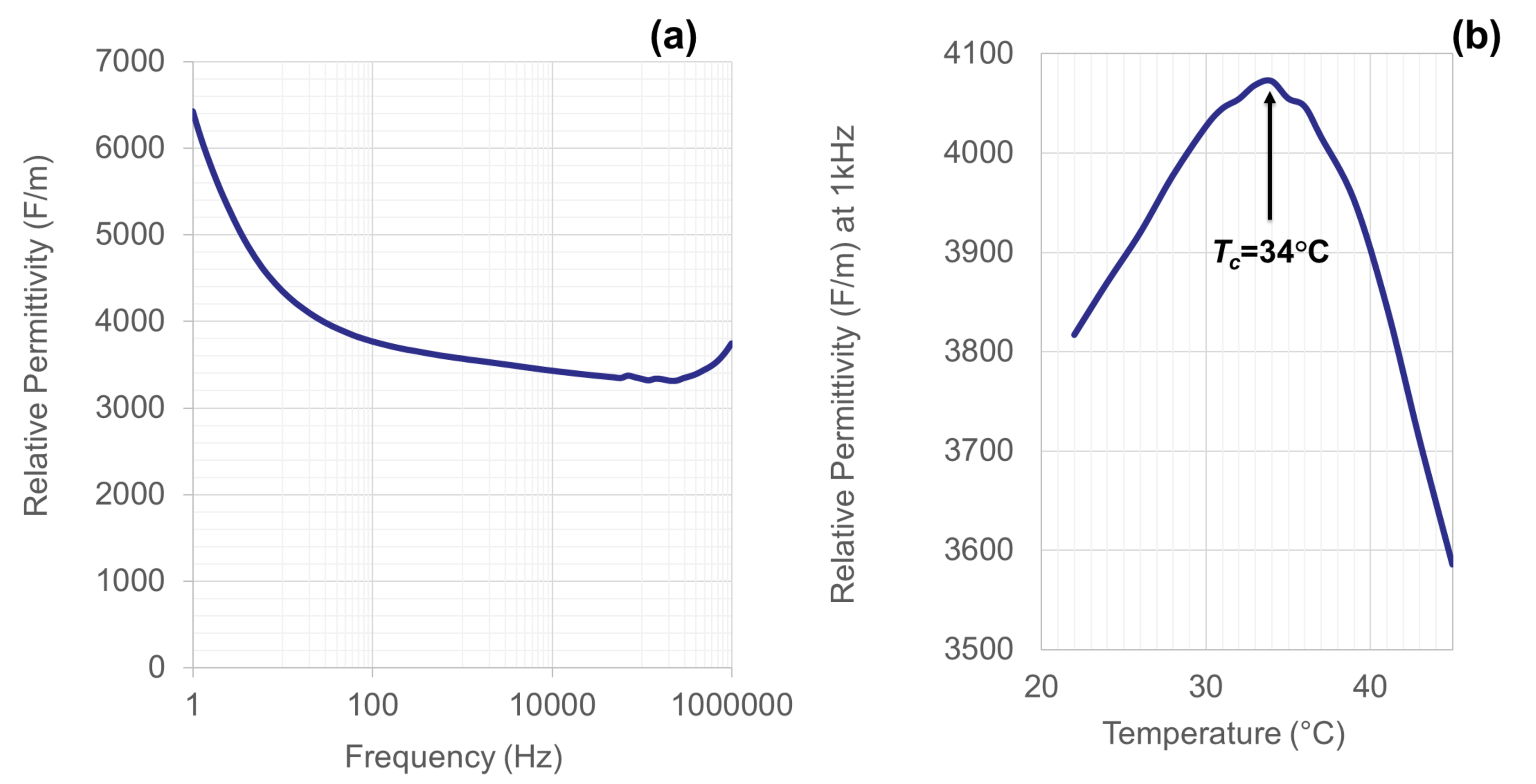


*Figure 4: (a) Relative permittivity vs. frequency for dense BST at room temperature and (b) relative permittivity (F/m) at 1kHz from 22°C-45°C, where the peak indicates the $T_c$ for a dense pressed tablet of BST.*

## Conclusions

The results of these initial pyro-electro-catalytic disinfection of water experiments were very promising, showing up to a significant 3-log reduction in viable bacterial cell counts. Within microbiology-based applications such as water decontamination and wound care a 3-log reduction is considered the “gold standard”. Overall, BST powders were successfully used in the pyro-electro-catalytic disinfection of cultured bacteria in solution.

## Future Work

- Optimise the materials and processes
- Experiments using samples of waste and effluent water
- Experiments using less temperature sensitive strains of E. coli, other bacteria strains and indicators commonly found in contaminated water

## References

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